SIMULATION STUDY OF EVACUATION CONTROL CENTER OPERATIONS ANALYSIS

GRADUATE RESEARCH PAPER

Christopher M. Olsen, Major, USAF

AFIT/IOA/ENS/11-4

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/IOA/ENS/11-4

SIMULATION STUDY OF EVACUATION CONTROL CENTER OPERATIONS ANALYSIS

GRADUATE RESEARCH PAPER

Presented to the Faculty of the
Department of Operational Sciences
Graduate School of Engineering and Management
Air Force Institute of Technology
Air University
Air Education and Training Command
in Partial Fulfillment of the Requirements for the
Degree of Master of Operations Analysis

Christopher M. Olsen, B.S., M.B.A.
Major, USAF

June, 2011

AFIT/IOA/ENS/11-4

SIMULATION STUDY OF EVACUATION CONTROL CENTER

OPERATIONS ANALYSIS

Christopher M. Olsen, B.S., M.B.A
Major, USAF

Approved:

//signed//	10 June 2011
J.O. Miller, PhD (Chairman)	Date

AFIT/IOA/ENS/11-4

Abstract

A Noncombatant Evacuation Operation (NEO) is the primary method employed by the US State Department of safely evacuating American Citizens and designated host country nationals from life threatening situations in foreign countries. Planning for these operations is difficult due to its dynamic nature and complex inter-department command and execution structure. Planning efficiencies could be realized through insights into dependencies and fundamental NEO operating characteristics. The Evacuation Control Center (ECC) is a main component in evacuee flow. This simulation study models ECC operations in Arena and varies key inputs and parameters to uncover the underlying elements that drive ECC output and performance. Evacuee arrival distribution, ECC manning, and evacuee wait times are the main parameters of interest.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

SIMULATION STUDY OF EVACUATION CONTROL CENTER OPERATIONS ANALYSIS

1. Introduction

The tumultuous political environment across the Arab world of mid to late 2010 continues to reverberate across the global. Stability seems to be decreasing on every front, but the United States has maintained its commitment to protecting the lives and interests of its citizens living abroad. This commitment manifests physically when a US Ambassador, in coordination with the Department of State (DoS), calls for the evacuation of American Citizens (Amcits) from locations in a foreign nation to a safe haven because their lives are in danger [Department of Defense, 2010]. This process is formalized as a Noncombatant Evacuation Operation(NEO).

Predictably, a NEO is a terribly complex process. Command and control, planning, resource allocation, and execution authority are just a few of the myriad elements that complicate thinking about a NEO. Many of these issues have been studied in recent years and some findings will be highlighted in following sections. The layout and functioning of just a small piece of a NEO, the Evacuation Control Center (ECC), is the chief concern of this study. However, to clearly lay out what this paper is going to address, it's beneficial to first spell out what it is *not* going to address.

1.1 Scope

To establish reasonable scope and focus, all considerations falling outside the sphere of the ECC won't be studied or addressed in the main body of this paper, but will instead be treated with a brief overview and a few observations. Of note, a distinct but related simulation and analysis effort of non-ECC NEO processes is concurrently underway. This companion study serves as the other half of a broader NEO simulation effort. Additionally, these two studies are an extension of a previous Air Force Institute of Technology (AFIT) Graduate Research Project (GRP) completed

last year. Major Aimee Gregg's work laid the foundations that served as a starting place for both the ECC refinement and overall NEO efforts [Gregg, 2010].

It is quite possible that many, or even the most significant, improvements to the NEO process may be discovered outside the ECC. Adjustments or revisions to larger NEO processes might have greater potential to enable mission success, like altering the method for securing evacuee transportation or restructuring the warden and notification system. However, the ECC is one of few pieces where significant uncertainty could be minimized because its operations and specific functions are predefined and designated by Joint Publication (JP) 3-68 and Marine Expeditionary Units (MEU) Standard Operating Procedures (SOP) and training. Before we dig into the ECC, a brief NEO overview will provide sufficient background and context for the bulk of this study.

1.2 NEO Background

Executive Order 12656, Assignment of Emergency Preparedness Responsibilities, identifies the Department of State as responsible for the protection or evacuation of US citizens and nationals abroad and for safeguarding their overseas property abroad, in consultation with the Secretaries of Defense and Health and Human Services [Reagan, 2011]. A Memorandum of Agreement Between Departments of State and Defense on the Protection and Evacuation of US Citizens and Designated Aliens Abroad has outlined the basic structure of responsibilities each organization bears in this process. Specific NEO execution is outlined in Joint Publication 3-68 as the blue print for all NEO operations. Command and execution lines of authority are very clear in this process. However, confusion is introduced with the vague statement:

> Operations at the evacuation site are clearly delineated between those performed by DOS personnel and those performed by the (Joint Task Force (JTF). However, in cases of emergency the JTF should be prepared to perform functions that are normally executed by embassy staff. JP 3-68, V-I

This requirement for the JTF to be able to execute operations without DoS support puts significant planning constraints on the Geographic Combatant Commander (GCC). The GCC is responsible to review each Embassys Emergency Action Plan (EAP), and ensure all necessary operational components are available. Once an evacuation decision has been made, the Amcit population will be notified through various means, and given instructions. Evacuees would then report to the designated location for processing and transportation. The real complexity and potential chaos of the situation cannot be adequately conveyed by the phrase 'processing and transportation.' Amidst a potentially degrading security environment, the security, verification, basic needs, and transportation of all evacuees must be provided for. While DoS personnel retain the ultimate responsibility for these actions, their uncertain force size and composition compounds planning complexities. In the face of this resource uncertainty, an optimized and flexible ECC process will enable maximum performance in the form of rapid evacuee processing.

The need for significant process improvement effort has been clearly highlighted by the after action reports of the 2006 NEO of Lebanon [Ford, 2007]. Initial classified reports suggest similar efficiencies could have been realized during the more recent NEO in Tunisia, Egypt, Libya, and Japan. Clearly, the Evacuation Control Center (ECC) processes warrant analysis. Key operation planners, responsible for the design of country-specific NEO plans, suspect the ECC contains inherent inefficiencies [Livingston, 2011b]. As such, they have been the main impetus behind this study.

1.3 Study Overview

This general NEO information will now guide a review of relevant literature and the search for other organizations or institutions who might have valuable information. Chapter 3 will layout the steps to conduct a simulation study, Chapter 4 highlights the results and analysis and Chapter 5 presents the results and conclusion.

2. Previous Research & Adjacent Efforts

2.1 Literature Review

The bulk of previous NEO literature reviewed focused on the challenges of conducting such a diverse and multi-organization operation. Doctrine, policy, and publication reviews have resulted in a number of well-constructed explanations of NEO process, and recommendations for areas to investigate further.

Any review of NEO doctrine quickly identifies its highly 'multi-organizational' nature. While coordination and support from outside organizations has been improving over the past few years, reliance on host nation support and non-governmental organizations should be minimized. DoS calls upon the Department of Defense (DoD) to unilaterally execute a NEO because of their expertise. Therefore, any Joint Task Force must have their organic forces and processes refined [Standifer, 2008].

Nine NEO 'Key Considerations' are outlined by Col Mark A. Davis in a 2007 Naval War College paper. They mostly cover non-ECC related concepts, but advance understanding of NEO complexity by enumerating specific areas for improvement. These considerations are: prioritization, reconnaissance, interagency joint and multinational planning conferences, better F-77 data, Joint Force HQ certification, rehearsals, anticipated demand for lift, determining who gets evacuated, and ROE and engagement authority [Davis, 2007]. A general understanding of all these are fairly self evident, with the exception of one, which requires a brief explanation. The F-77 is essentially a living roster of all Amcits residing in a particular foreign country, maintained by the US Embassy. It is the responsibility of the individual to update their information as required, and therefore the accuracy of this record can be called into question. With regard to mission rehearsal, simulation is singled out as a promising method.

> Rehearsals can also be executed in simulation. A realistic constructive simulation could be modeled to replicate a NEO. This would greatly assist planners in visualizing their course of action, determining the capacity of key nodes....and the expected duration and through-put in these key nodes.

These findings and discussions are valid, but remain mostly in a theoretical planning, higher-level sphere. More specifically, the concepts and processes that drive the ECC are referenced in passing, but no analytical modeling effort to 'engineer' the ECC was discovered. Fortunately, the concepts of process analysis and refinement have significant application in a large number of other areas, many of which are loosely related to NEO. While these adjacent disciplines have varying degrees of overlap with a NEO, any serious attempt to model and refine the ECC should at the very least consider relevant findings and insights uncovered in these other areas.

2.2 Transferable ideas

Disaster relief planning shares the common thread of rapidly transporting a great number of people in a very dynamic environment. The disaster of hurricane Katrina brought emergency evacuation planning and execution into the national consciousness and vocabulary. The increased attention of emergency planning has precipitated a number of sponsored research efforts. Agencies at all levels are looking to construct, update or refine their emergency plans and are increasingly turning to academia and research to assist in these efforts. Both the Department of Homeland Security(DHS) and the Texas Department of Transportation have partnered with the Industrial Engineering Department at the University of Houston (UH). These organizations hope to leverage the simulation and engineering capabilities of the university to refine the Hurricane Evacuation plan for the city of Houston [Lim, 2011].

Obviously, the scale of evacuating an entire metropolitan area is different than a NEO. Dr. Gino Lim is the lead UH faculty for this effort, and shared a concept they are exploring that has NEO implications. The idea is summarized as follows: as the time until an impending event decreases, the range and scope of Courses of Action (COA) available to a decision maker also decreases. With 24 hours until projected hurricane landfall, there are more evacuation options to move more people to safety. With every passing hour, the list of evacuation measures that could be executed in the remaining time gets smaller. Dr. Lim is focusing on robust optimization of a network

flow model using buses to evacuate the city [Lim, 2011]. While not exactly the same, these types of efforts provide useful insight for the NEO problem. Accountability, speed and safety are driving factors in both scenarios.

In addition to the speed of evacuee processing, there is a psychological component to these types of operations. Processing and transporting people in a stressful and possibly dangerous environment deserves some 'people-focused' attention. Operational success is sometimes driven by the perceptions of those directly involved, and can be defined by public opinion. The ubiquitous media and near real-time global information sharing has enabled a single individual or single media 'event' to have immediate and direct ramifications to not just the operation itself, but also to the perception of mission success. This phenomenon is often dubbed the 'CNN-effect' can drastically sway public opinion of how the United States has handled or is currently handling the delicate and highly visible operation of protection and evacuation of citizens. In this context, there will certainly be international media, and any evacuee who is sufficiently dissatisfied with their situation would easily have an outlet and eager audience for their complaints. In addition to attempting to refine ECC operations, NEO planners at European Command (EUCOM) wondered if there would be a way to mitigate the chance of 'customer' dissatisfaction to mitigate the risk of a damaging media event in the midst of or following a NEO.

One industry leader that is consistently recognized as superbly managing customer perceptions and experience is Disney. The company employees a team of industrial engineers who look to apply their craft to varying functions and processes throughout Disney operations. Receiving, processing, and transporting large number of people, while giving each one a sense that they are being taken care of is a quality that can be seen in both Disney operations and a NEO. Discussions with a Lead Industrial Engineer at Disney, Peter Buczkowski, provided insight into how they apply simulation to some park functions.

Arrival rate and function service time distributions are closely monitored and used to make recommendations to Disney operations to improve the guest experience [Buczkowski, 2011]. In a modeling effort of a new resort restaurant, Mr. Buczkowski relayed a scenario they were studying that might also have similar characteristics to a NEO. There is some relationship between wait time and customer satisfaction. A family of 4 with no reservations might balk and walk away if told wait time for a table was 20-25 minutes. They might stay if the wait was only 10. Their satisfaction would also vary if their food arrived 9 minutes after ordering, versus 29 minutes. Their level of satisfaction would slide along some scale that accounted for many factors, including wait times [Buczkowski, 2011]. Another concept Mr. Buczkowski related was that of a process factor based on number of individual in a family. For example, a process that takes two minutes for an individual will probably take a party of two more that just two minutes, but probably less than four. There is a scaling factor for the variable elements of process time that changes as family size increases.

Armed with the concepts and insights gained from previous research and adjacent efforts, the following modeling methodology section will outline the process of ECC model conceptualization, and constructing the concept in Arena.

3. Methodology

Discrete Event Simulation (DES) offers a powerful way to observe complex interaction within a dynamic process. Several relevant advantages of simulation are spelled out in current academic literature. A leading DES textbook lists, among others, the following advantages [Banks, Carson, Nelson, and Nicol, 2010].

- New policies, operating procedures...organizational procedures, and so on can be explored without disrupting ongoing operations of the real system.
- New...physical layouts...can be tested without committing resources for their acquisition.
- Bottleneck analysis can be performed to discover where work in process...are being delayed excessively.
- A simulation study can help in understand how the system operates rather than how individuals think the system operates.
- “What if” questions can be answered.

It should be apparent from the previous NEO discussion that many of the desired insights are right in line with the advantages of simulation. The operation of an ECC, with evacuees processing through various stations, is particularly well suited to be studied via a simulation. Banks et al then go on to outline the steps a ”thorough and sound simulation study” should include [Banks et al., 2010].

1. Problem formulation
2. Setting of objectives and overall project plan
3. Model conceptualization
4. Data Collection
5. Model translation
6. Verification
7. Validation
8. Experimental design
9. Production runs and analysis

This list of nine items serves as the backbone for the remainder of this section and those that follow. In order, each section addresses how these steps were applied in this study.

3.1 Problem formulation

It is believed that efficiencies exist within the ECC that remain to be realized. As one of the few NEO processes that can be somewhat controlled and altered during the standard planning cycle, identifying potential bottlenecks, understanding how an ECC might function under varying input scenarios, and being able to alter structure and flow might provide useful insight to planners. Additionally, analysis of an alternate ECC structure that was capable of giving priority to certain evacuees would be equally beneficial. One theory states that some evacuees might be more likely to respond unfavorably to perceived unsatisfactory ECC handling. If these particular evacuees could be identified and handled somewhat differently within the ECC, their overall processing time, and hopefully their perception of poor service could be improved. They may therefore be less likely to convey negative sentiment if given the opportunity to express their assessment of the operation. For brevity, from this point forward, these particular evacuees will be referred to as Bad Press Evacuees, or BP evacuees for short.

3.2 Setting of objectives and overall project plan

This study aims to determine if any factors, reasonably within DoD or DoS control, could be adjusted to alter ECC performance with practical significance and improve meaningful measures of effectiveness. An overview of the plan could be summarized as; use Arena to model the ECC as currently prescribed, run three different arrival distributions through two different manning schemes, then construct an alternate structure to handle the BP evacuees. At this point it is worth remembering this paper is just one of two pieces in the larger NEO analysis effort. Similar efficiencies and insights are sought in the analysis of the non-ECC aspects through another simulation effort. Ultimately, a submodel architecture is desired wherein the ECC from this study could be placed into the model from the companion effort to observe complete system performance.

3.3 Model conceptualization

To realize the submodel architecture just mentioned required a common baseline model concept for both studies to being with. WIth such a complex and dynamic system, some initial simplifications were made by determining what would not be included. All factors leading up to the first family arriving at the front door of the ECC were discounted as being outside the model. It is possible that in this discarded set of factors are some which are critical to NEO success, however they don't lend themselves to inclusion in this simulation model. Evacuee arrival at the temporary safe haven defines the boundary on the other end of the NEO. Additional intermediate transportation steps taken to arrive at the permanent safe haven (usually considered as arriving in the United States) are also not considered. With these bookends on the process, the basic plan is to create a simulated environment through which evacuees flow, starting by arriving at the ECC with bags in hand, ready to leave the country. They then proceed through the main steps of ECC processing, transportation to a port, and transportation to a temporary safe haven. This paper covers the ECC processing, while the second and third steps are covered in the companion study.

The decision maker's concern for efficiency and NEO execution time drove the development of two overriding concepts, which in turn laid the foundation for some key modeling decisions. Wait times and processing times were the main areas of interest, so entity handling and attributes were designated and assigned with respect to how they would effect these times. For example, if a single member of a couple needed to receive extra attention at a medical processing station, as far as timing is concerned, it doesn't matter which member of the couple needed the vaccination. The key effect was that the couple delayed a little longer at the medical station for someone to receive extra attention. This first of two governing thoughts is summarized as: if it doesn't effect wait time, process time, or ability to process evacuees out of country, it probably doesn't contribute enough to justify inclusion in the model. The second overarching idea is to include only those elements require to sufficiently characterize the real system until a useful approximation results [Banks et al., 2010].

These ideas were first applied to determining that a family unit was the entity to flow through the model. These family units ‘arrive’ at the ECC after being ‘created’ within a simulation at some rate. The actual rate they’ll arrive at is unknown, so the study will assume three different scenarios and compare how the system performs under the pressure of these different arrival rates. There rates were conceptualized as: ‘Mad Rush’ - most arrive early in the arrival period, ‘Orderly Departure’ - a constant average arrival rate throughout the entire window, and ‘Hesitation’ - most wait until the back side of the window. Specifics for these distributions will be addressed in the Model Translation section.

Obviously, not all families are the same. Some of these differences won’t effect processing times. However, those characteristics that will must be attributed to families to facilitate this abstraction of reality. These heterogeneous characteristics are assigned to an entity as an attribute, so it arrives and flows through the ECC with a certain assigned set of parameters. The first of these characteristics is the size of the family unit. Based on the detailed products from the 2000 US Census, Table 1 spells out these attributes, and gives the distributions for particular characteristics assigned to each family unit [Bureau, 2011].

Table 1 Evacuation Unit Size Distribution

Evacuee Unit	Distribution of entities created
Single	30%
Couple	32%
Family of 3	17%
Family of 4	14%
Family of 5	7%

These created entities have characteristics associated with them that effect the speed at which they proceed through the various stations in the ECC. Various levels of a characteristic will translate into different processing times. Table 2 summarizes these characteristics, only half of which will be utilized when the baseline model is translated into Arena. ‘Medical Attention’ serves as a good example. Eighty percent

Table 2 Entity Attributes

Entity Characteristic Distribution			
Characteristic	1	2	3
Interviewed	75%	25%	-
Medical Attention	80%	18%	2%
Bad Press Potential	90%	10%	-
Assigned / not utilized			
# Females (fam of 3)	45%	45%	5%*
Have pets	70%	30%	-
Priority Evacuee	90%	10%	-

* and 0 fem

of the family units arriving at the ECC will not require additional medical processing, 18% minor medical attention, and 2% significant attention. Again, it doesn't matter what the reason for the attention is, but these different attributes will eventually translate into processing times of varying lengths.

The final component of the real system that must be abstracted is the work that is done for each entity as it proceeds through the ECC. There is a great number of quantifiable measures that could be captured with regards to work being done. Besides elements of time, examples of observable measures are raw materials consumed, fixed costs, or variable costs. Given a different set of concerns or goals, these would be relevant measures. However, given the desire to understand how the systems interactions effect considerations of time, there are three elements required to abstract the work done into a conceptual model: the station, the worker, and the time required to complete the work.

Figure 1 is a picture of general ECC stations as outlined by JP 3-68. This process outlined is reduced to six general stations; reception, searching, screening, interview, medical, and registration.

Next, someone must do the work, and these human resources are not unlimited. If workers were unlimited, an evacuee population would process much quicker. It is

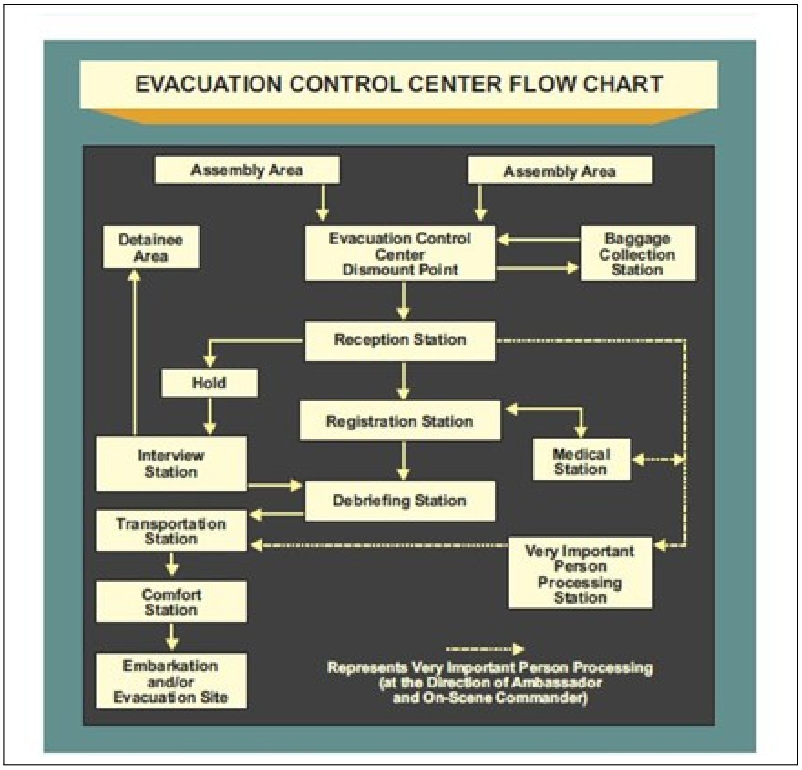


Figure 1 ECC Study Flow [Department of Defense, 2010]

not difficult to see that ECC output performance is limited by the number of workers employed at each station, so this element is incorporated by requiring a resource for work to be done at this station. Since there are a discrete number of workers available, when an evacuee arrives at the station and all workers are engaged with other evacuees, they will have to wait for a worker to become available. The number of workers available for each process can then to altered to observe effects on system performance.

Finally, the tasks done at each station will take a certain length of time. Since these tasks involve human interactions and other non-deterministic elements, task lengths will not be identical for each evacuee. An average service time may be approximated, but the actual times for a specific evacuee will fall within a range of probable times compared to the mean. As such, the time required to perform work at each station will be represented by a triangular distribution, with a most likely, minimum, and maximum value.

To summarize the model conceptualization, an evacuee family unit with assigned attributes will proceed through six stations, where work will be done by a finite number of workers, whose service time will follow a predetermined distribution.

3.4 Data collection

The fuel that runs a simulation is the data that allows a model to be an accurate abstraction of reality. The nature of NEOs and their relative infrequency have resulted in a significant lack of data. Some processes lend themselves to repeatable observations, such as front gate operations at Dinseyland, where an observer could observe and record statistics of interest like family size and time to check them in. The most readily available data for NEOs that have been executed is the number of evacuees transported and the length of time it took to perform the evacuation. The F-77 data for each country is available, and provides an approximate number of potential evacuees in each country. The accuracy of this number is often questioned, and varies based on update frequency and method. Unfortunately, this document provides none of the categories needed to complete Tables 1 and 2 of this study.

Instead, reasonable approximations for these figures were obtained from US Census data from 2000, as 2010 Census results have not been completely compiled and released. Foreign population statistics are obviously available, but it is generally not the local population a NEO is concerned with, but instead the Amcits. It is difficult to conceive of reasons why this Amcit population would be drastically different that the US population at large. As previously mentioned, there is very little data available for actual NEO situations. Therefore, insight into potential evacuee arrival were estimated through discussion with the Disney Industrial Engineer office. Without divulging their proprietary data, he shared that very often arrival data follows a triangular distribution. This concept will be incorporated by specifically defining the average evacuee arrival rates over a 48 hour period in the Model Translation Section.

While JP 3-68 spells out the ECC stations and flow, it does not prescribe manning levels. The most reliable source for these numbers was Mr. Mike Livingston,

Table 3 ECC Manning

Designated Personnel per Station			
Station	BLM*	BLM + 50%	BLM + 3**
Reception	1	2	2
Search	3	5	4
Screening	4	6	4
Registration	4	6	4
Medical Processing	2	3	2
Interview	1	2	2

* Baseline Manning

** adds 1 DoS rep for Reception, 1 Interviewer, and 1 Searcher

subject matter expert (SME) from EUCOM with extensive personal experience in training and running MEU ECC training and execution. He created a deck of Power Point Slides to train MEUs during their spin-up prior to deploying, which constituted the bulk of the official technical guidance [Livingston, 2011a]. The number of MEU personnel recommended for each station process is outlined in this guidance, and served as the source of baseline manning. Anticipating that ECC manning levels will be varied during system analysis to gain insight into performance, Table (3) shows the baseline and two alternate manning structures for comparison. The first alternative increases manning at each station by 50% across the board. A potentially more feasible and impactful manning increase calls for DoS to augment both their Reception and Interview manning by 1, and DoD to add 1 server to whichever stations immediately follows reception. This station happens to be the Search process in this layout, and the increased capacity at this station should help absorb the work load when each Reception session ends and 10 evacuation units (families) arrive.

The last piece of data required to support the conceptualized model are the service times for the individual processes and who is required to complete the work. As expected, there is a lack of data for the reasons previously listed. However, in this case, a small bit of reasoning and observation of similar processes served as an initial approximation. These reasoned values were refined using the assumed average

output of the system provided by the SME [Livingston, 2011b]. Table 4 shows the minimum, most frequent and maximum values used in a triangular distribution to represent the five and the six service times. The medical processing time utilizes a fixed and variable component to represent the time required to provide medical service to evacuating families. Regardless of the number in the family, there is a minimum time of two minutes, plus a variable factor equal to twice the number of evacuees. Finally, the workers required to complete the work is shown by station in Figure 5.

Table 4 Process Service TIme

ECC Station Service Times			
Station	Minimum	Most Frequent	Maximum
Reception	8	10	12
Search	2	3	4
Screening	1	3	5
Registration	1	3	5
Medical Processing	2 min + processing factor		
Interview	3	5	10

Table 5 Station Manning Requirement

Station	Worker Required
Reception	1 DoS
Search	1 Searcher (DoD)
Screening	1 Screener (DoD)
Registration	1 Data Entry (DoD)
Medical Processing	1 Medical
Interview	1 DoS & 1 Counter Intel

The scaling factor mentioned by the Disney IE referenced in Section 2.2 is also incorporated into these process times for Search, Screening and Registration. Economies of scale are recognized at these stations, but the model must account for work done for each individual family member as the family unit entity flows through the model. This scale factor is based on the Evacuation Unit Size attribute described

in Table 1. Table 6 shows how a scale factor captures this reality in an example Search process. The actual application of this factor is addressed in the next section and shown in the 'Basic Processes' block of Figure 16.

Table 6 Scaled Process Time for a 3 minute pull from TRIA (2,3,4)

Number in Family	Scale Factor*	Process Time (min)
1	1.2	3.6
2	1.4	4.2
3	1.6	4.8
4	1.8	5.4
5	2.0	6.0

*Scale factor = (1 + (Num in Fam * 0.2))

3.5 Model translation

This section will describe the steps taken to translate the conceptual model into Arena, the simulation software for this study. Reference to tables in previous sections will minimize repeating information already presented. Four main components make up the substance of this section: entity creation, attribute assignment, resources, and service times. These will be treated in turn. The main Arena structure and three submodels are shown in Figure 2.

Entities must first be created in order to flow through a simulation and in this study the entity is the Evacuation Family Unit. Two main characteristics of this creation function is how many entities to create, and how often. Selecting the number of entities to create is a function of historical NEO data, SME opinion, and system design. For the baseline configuration, the ECC will run 24 hours/day, for 2 days, with 2100 entities created over the 48 hour period. Three different arrival distributions were created in an attempt to capture different evacuee behavioral responses to a NEO order. Arena creates entities using an exponential distribution to represent a Poisson arrival process, with the characterizing parameter of μ, average number of entities per hour over each defined period. This parameter was altered across twelve 4-hour time periods to create an arrival distribution. Three sequences of 12 parameters form

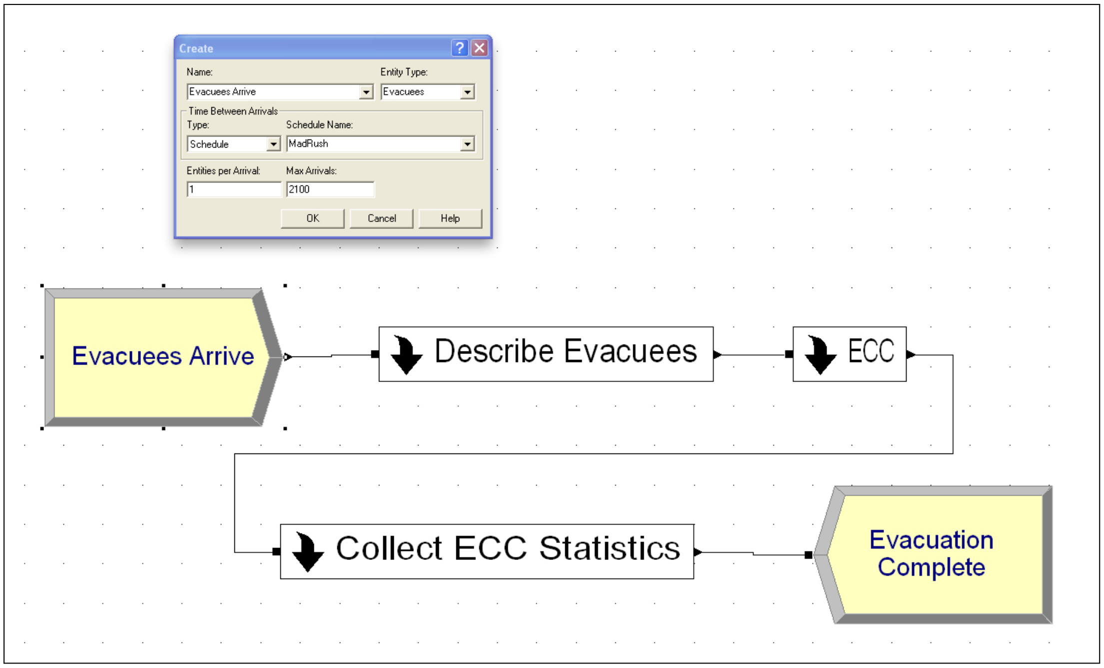


Figure 2 Arena - Create Entities

the basis for the different arrival distributions to be studied: the Mad Rush, Orderly Departure, and Hesitation are shown in Table 7.

It is improbable that an Amcit evacuee population would behave by arriving at the same hourly rate rate across all periods. However, it is assumed that this hypothetical steady arrival rate would minimize the 'stress' on the ECC and consequently yield the best system performance. This 'Orderly Departure' case will serve as a basis for comparison for the other two hypothesized distributions. The 'Mad Rush' is an arrival schedule heavily weighted toward the beginning of the 48-hour period. The 'Hesitation' schedule delays the bulk of the arrivals toward the end of the period by flipping the list of 12 Mad Rush averages.

The effect of an arrival distribution built upon these varying hourly averages can be seen in histograms from a single Arena replications from each schedule. These graphs depict an example arrival pattern, but subsequent replication will be unique due to the random numbers used. Figure 3 shows that even though the average

Table 7 Arena Entity Arrival Distributions

Average Arrivals per Hour			
Hours	Orderly Departure	Mad Rush	Hesitation
0-4	44	45	20
5-8	44	75	25
9-12	44	65	30
13-16	44	60	30
17-20	44	55	35
21-24	44	45	40
25-28	44	40	45
29-32	44	35	55
33-36	44	30	60
37-40	44	30	65
41-44	44	25	75
45-48	44	20	45

arrivals per hour are constant, the exponential distribution of the Poisson arrival process still generates a more scattered result than a pure uniform distribution.

The Mad Rush effect is evident in Figure 4 with the bulk of the graph (and arrivals) being earlier in the time period. The Hesitation can easily be seen in Figure 5 as a reflection of the Mad Rush, as expected from Table 7.

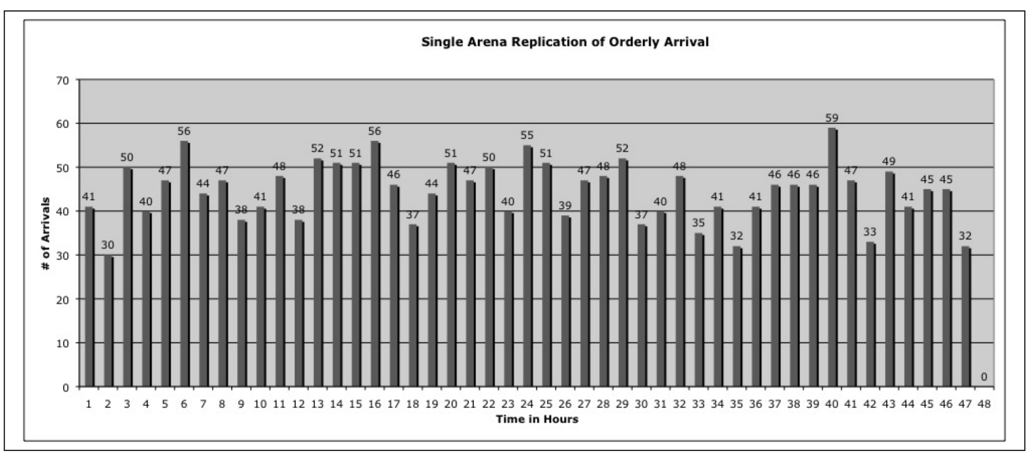


Figure 3 Orderly Departure Arrival Example

Next, entities take on certain attributes after being stamped with these characteristics in an Assign Block. Specifically, a submodel named 'Describe Evacuees' is

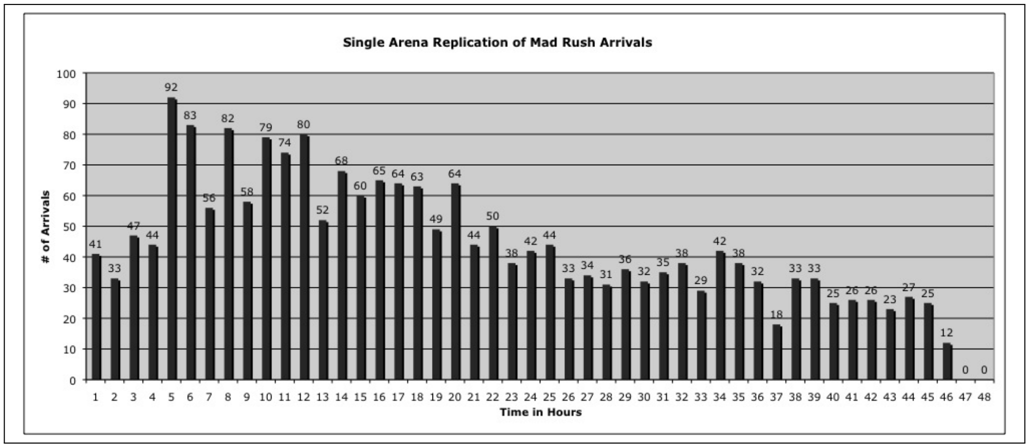


Figure 4   Mad Rush Arrival Example

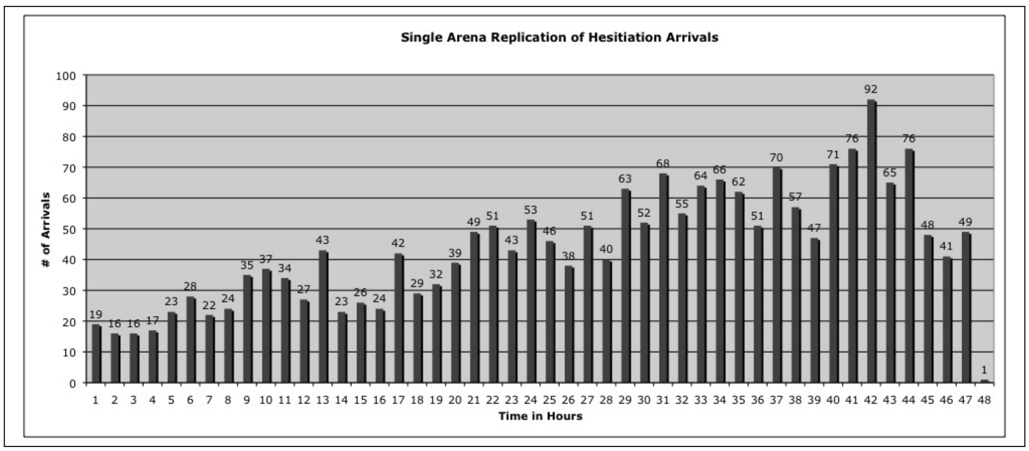


Figure 5   Hesitation Arrival Example

used to execute a few functions before the entities enter the system. Each evacuation entity is assigned attributes according to Tables 1 and 2. Additional assignments and functions take place here which enable key statistic and timing collection. The Create block and associated Dialog box used to input the specific parameters and arrival schedules are shown in Figure 2. The Describe Evacuee submodel is expanded in Figure 6.

The heart of the simulation is the ECC submodel shown in Figure 7. The actual stations that an evacuee would flow through are constructed here. A descriptive 'walk-though' of this submodel is appropriate at this point to explain how the Arena elements serve to model the actual functions that take place inside an ECC. The

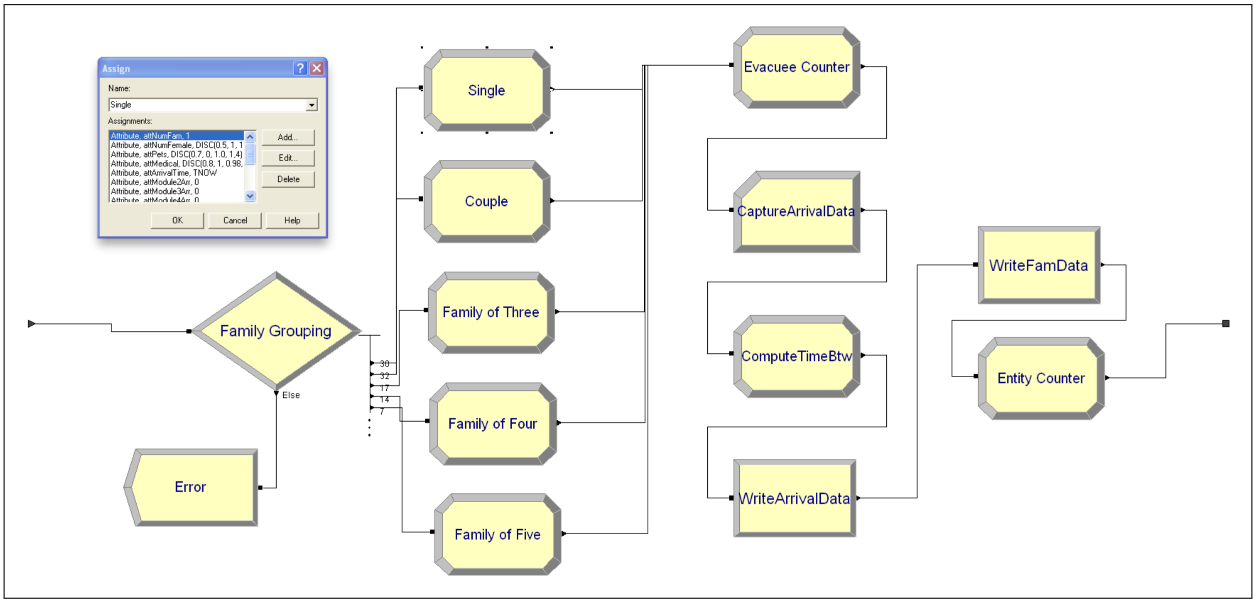


Figure 6 Arena - Describe Submodel

entity flows from left to right in the figure and first wait until 10 entities arrive to receive an initial briefing.

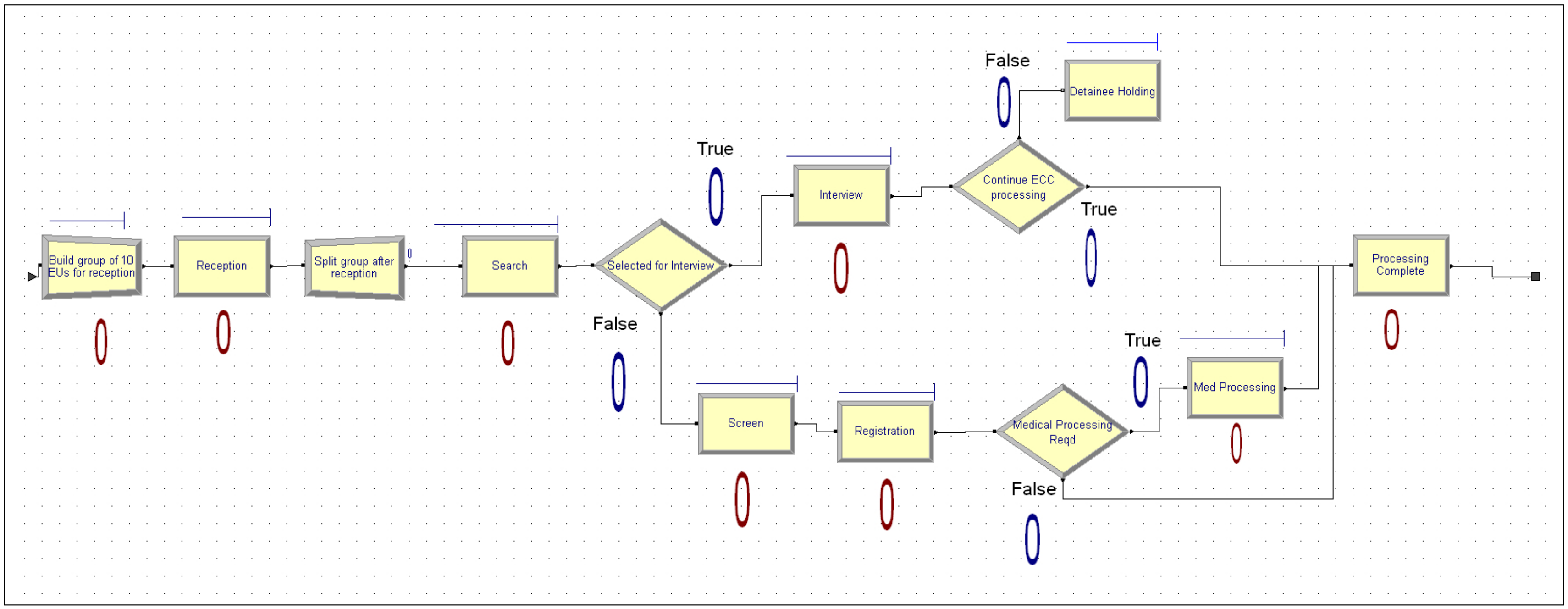


Figure 7 Arena - Evacuation Control Center Submodel

After the briefing, the families proceed to a Search station, where 3 searchers are available to perform searches of the families and their luggage. The Dialog box for the Search process is shown in Figure 8. The diamond labeled 'Selected for Interview' is a logic element in Arena, used to direct evacuees with a randomly assigned Interview attribute to the interview station.

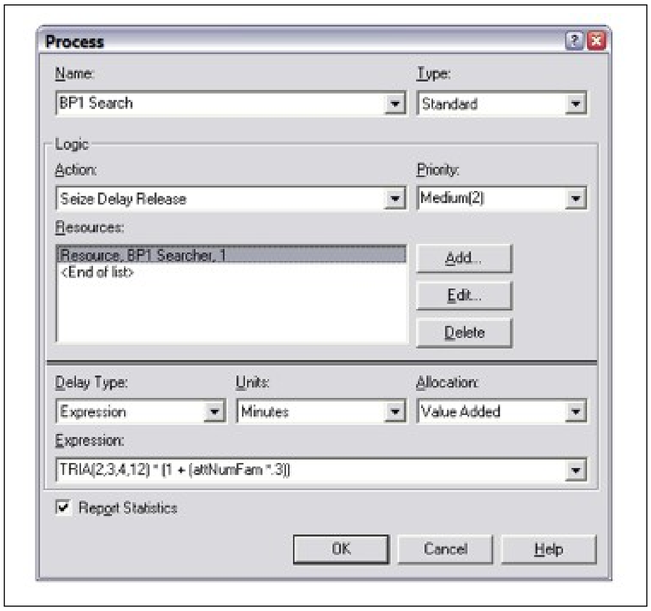


Figure 8 Arena - Search Process Dialog Box

Personnel characteristics are input as Resources, specific task parameters are built in the processes, and logic flow elements exist in the Decide elements. The specific data to model these underlying elements are summarized in Figure 16 in Appendix A. These match the parameters outlined in Tables 3 and 4.

Finally, a submodel is employed to collect the data and statistics of interest in order to analyze the effects of varying arrival distributions and manning levels. A depiction of this structure is shown in Figure 15 in the appendix. Arena has many built-in statistics that it collects, including many timing elements. Wait times are recorded per entity for each queue and statistics are easily collected for these times.

3.5.1 Alternate ECC Structure. To support the investigation of evacuee dissatisfaction and their propensity to present a negative report to the media if given

the chance, an alternate structure was constructed. Evacuees identified as having a greater likelihood for this characteristic were diverted to stations dedicated to them, serviced by resources reserved for them. A small section of this alternate structure including areas of parallel processing are shown in Figure 9 . To facilitate discussion, from this point forward, this characteristic will be referred to as a Bad Press (BP)Potential. Evacuees having this increased likelihood of expressing dissatisfaction will be termed BP 2s, in contrast to all other evacuees, BP 1s. The distribution of BPs in the system are 90% BP 1 and 10% BP 2 as presented in Table 2. Since all individuals within an Evacuation Family Unit move through the ECC together and will generally experience the same wait times, this characteristic is assigned to the entire Evacuation Entity and not an individual person. It is understood that the entire family experiences the ECC process, but generally it would only be one individual who would express dissatisfaction. A scoring structure was constructed as

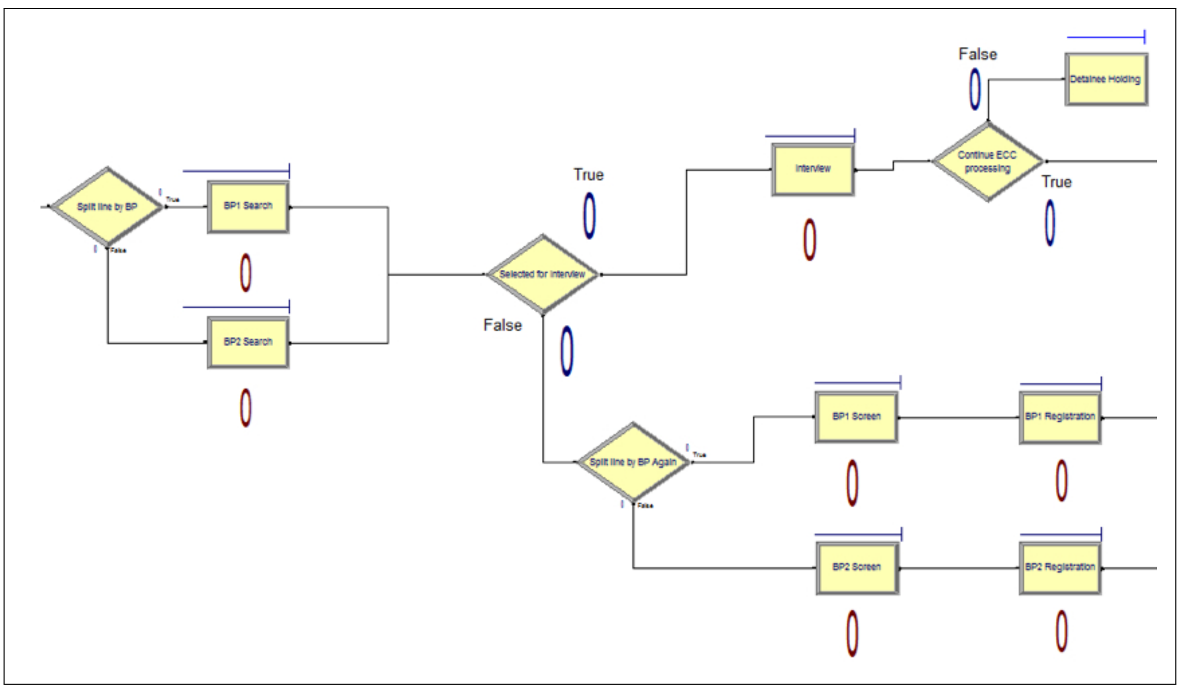


Figure 9 Arena - Alternate ECC Structure

a way to quantify evacuee dissatisfaction. This construct was fairly arbitrary, but simple to understand and implement, as everyone has spent time waiting in line, and

understands varying levels of frustration associated with these waiting experiences. As with many aspects of simulation, the power of this structure is not in the actual value of the score, but in its ability to be recalculated under different conditions and compared. A perfect Bad Press Score (BPS) is 100 and decreases the more time an evacuee spends waiting in line. Again, it is the time spent waiting in line that is of interest, not the time spent being taken care of at each station.

There are two schedules of BPS reduction presented in Table 8. This is to capture the reality that the same wait time for both a BP 1 and a BP 2 would most likely result in different reductions in satisfaction. To illustrate, a lone individual (a BP 1) may have a certain level of dissatisfaction after waiting in line for 25 minutes. Now, if accompanied by 2 children and an elderly parent (now classified as a BP 2), this same 25 minute wait time might certainly yield a greater level of dissatisfaction. Figure 15 in the appendix shows how these scores are assigned and tallied in the Statistics Collection Submodel.

Table 8 Bad Press Scores - Dissatisfaction based on wait time

Total ECC Wait Time	BP 1	BP 2
00 - 15 minutes	95	90
15 - 30 minutes	80	70
30 - 60 minutes	65	50
$\geq$ 60 minutes	40	20

100 = completely satisfied, zero 'Bad Press' potential

3.6 V & V, Running the Model, and Analysis

The final 4 steps of a simulation study outlined by Banks et al at the beginning of this chapter are only briefly addressed here, as they are the substance of the remainder of this report. Verification is the process by which the translated simulation model is scrutinized to ensure it is operating properly. Even if the model runs exactly as it was programmed to do, the model must still be validated to ensure it is accurately representing actual system behavior to the level required. Experimental

design elements of run length, parameters and structures to be altered, initialization, and replications must then be determined. Finally, the runs will be conducted and analyzed.

4. Simulation Results & Analysis

This chapter begins by highlighting the way the model was verified and validated. Subsequent sections go on to simultaneously present simulation results while offering an analysis of those results along side them. This mirrors the reality of the iterative process that was undertaken in the study: run the model with a given set of parameters, observe the results, decide what the results are saying, adjust the model, and run the model again with new parameters to explore another aspect of the system. A numbering system was used to describe the runs for ease of bookkeeping and to facilitate succinct discussion reference. These reference numbers are shown in Table 9.

4.1 Verification

The model was constructed in Arena in the manner spelled out in Section 3.5. However, it must be checked to ensure it is functioning properly and does in fact represent the real-world system with sufficient accuracy. These steps are verification and validation. First, verification will determine if the Arena ECC operation matches that of the conceptualized model. The process started with a single run of 100 entities, utilizing the animation feature of Arena to observe the generated icons move through the constructed ECC while simultaneously referencing the simulation clock. Observing entity flow through the model was a useful method to debug logic and structure errors. The batching and separating functions worked correctly as entities arrived

Table 9 Simulation Run Reference Number

Arrival Dist.	BLM*	BLM+50%	BLM+3**	Alt BP Structure***
Mad Rush	2	5	8	11
Orderly	1	4	7	10
Hesitation	3	6	9	12

* Baseline Manning
** adds 1 DoS rep for Reception, 1 Interviewer, and 1 Searcher
*** Alternate ECC Structure with BLM + Target Plus-up manning

and departed the reception station. Entities continued to flow through successive stations, with entities stacking up in queues as the servers at each station 'worked their way through' the evacuee entities waiting in line. No queue was overwhelmed by entities, showing that the entity processing time attributes, and service times were working together well. Next, the statistics of interest were observed to confirm that they were correctly tallying, analyzing and reporting what they should be.

Once the model was verified with 100 entities, the number was increased to 2100 entities that arrive based on one of the three schedules presented in Table 7. The model was able to handle all three of these arrival schedules, and the statistics were moving in anticipated directions. Without requiring any statistical analysis at this point, the model was considered verified, as functioning in the way that it was conceptualized.

4.2 Validation

It is possible for a model to be verified but still not accurately represent the real-world system it is trying to capture, thereby almost negating any valuable insight it may lend to a decision maker. To prevent this from happening, the Arena model must now be validated to ensure the constructed model represents the system of interest with required accuracy to meet the simulation study objectives. Due to the random nature of attribute assignment and processing times, multiple replications are required to generate a representative picture of likely operation. The single run used in verification is not longer sufficient, and was increased to 20 so an average of each parameter of interest could be calculated to provide a better sense of expected performance over time. Additionally, it is important to note when comparing these numbers that the Arena model runs 24 hours/day throughout the period of evacuee arrival, and remains operational until all evacuees are processed.

Another concept worth mentioning at this point is random number synchronization. The stochastic nature of many of the characteristics within the ECC are simulated through the use of random number generation and assignment. In order to

make effective system adjustments, it is useful to have the same random numbers used when a run is repeated, so changes can be correctly attributed to the adjustments, and not the selections of a different set of random numbers. Synchronization of random numbers is accomplished through a mechanism called streams, which ensures the same random numbers are 'pulled' and assigned for the same purposes, on the same replication, for alternative systems. This synchronization also has the effect of reducing the independence of the results. For the purposes of this study, a statistical test called a Paired-T test will be the test of choice. This test allows for parameter comparisons without independence and is addressed in the following section.

With these concepts spelled out, model validation can begin. ECC wait time and processing data is required for this procedure. Section 3.4 previously spelled out the challenges of acquiring this data and highlighted how Mr. Livingston's personal experience would form the basis for this data. At this point, his statements of hourly ECC output and total evacuee processing numbers were used to make minor adjustments to the service times. These minor adjustments resulted in the values previously presented in Figure 4. Dividing the total number of individuals processed by the completion time in hours, the average number of evacuees processed per hour was compared to the SME's projections. He stated that they often planned being able to process 50 to 60 evacuees per hour, but the number could improve slightly from there. He strongly dismissed the idea that 100 per hour is a reasonable starting point for this value [Livingston, 2011b]. The After Action Report and Lessons learned from the 2006 NEO of Lebanon was also used as a reference to validate ECC model performance [Ford, 2007]. Based on these sources of ECC performance data, the ECC model was verified and validated.

The remaining sections in this chapter will step through the runs that were conducted, highlighting and analyzing the results of those runs, and offering insight as to what the data might be pointing to when appropriate. As Figure 9 shows, the runs naturally fell into batches of three because of the three arrival distributions.

Successive batches alter the manning structure of the ECC, and run the same three arrival distributions again.

4.3 Baseline Manning (Runs 1, 2, & 3)

The prescribed ECC manning was used in the system to establish a baseline for comparison of future runs. The computer completed the 20 replications of each run quickly, capturing the results and presenting them in a number of reports. Key results and relevant comparisons for these first three runs are addressed.

The paired T test was introduced in the previous section and will be the primary method used to determine if there is a statistical difference between the means of parameters of interest. Using a formal hypothesis test, the paired T asserts that the arithmetic mean of the difference of a performance measure from two systems is equal to zero. If there is enough evidence to refute this claim, this hypothesis is rejected. Arena Output Analyzer depicts the results of this test using a 95% confidence interval. If zero is contained within this interval, the mean difference might be zero, indicating there is no statistical difference between the performance measure of interest for the two groups. The graphical and textual results of this test accompany the following discussions.

4.3.1 Baseline Statistics Interpretation. Wait times, sources of delay, and resource utilizations are the first area of interest. The statistics from Run 1 point to three of the stations as the main contributors to increased entity wait time. Table 10 shows the accumulated wait times for each station. This is the total time all entities spent waiting in each line. While the exact values are not terribly meaningful, the relationship between them provides the key insight. Additionally, the relationships between **per entity** wait times show the same results. Namely, reception, search and interview stations are contributing the most to entity wait time.

The large accumulated wait times at reception are understandable given that nine entities will have to wait for the tenth to arrive until the reception briefing

Table 10 Average Family Wait Time per Station (in minutes)

Station	Run 1	Run 2	Run 3
Reception	11.1	28.1	13.7
Search	270.6	361.9	196.9
Screening	≈ 0	≈ 0	≈ 0
Registration	≈ 1	≈ 1	≈ 1
Medical Processing	≈ 1	≈ 1	≈ 1
Interview	101.9	249.0	127.1

begins. Once they are released from this briefing, all ten of them move to the search station, where three workers begin processing them. With the assumed service time distribution at this station, these workers cannot get through all ten entities before the next batch of ten are released from their reception briefing. This is a clear sign of a bottleneck in the process. After an entity eventually gets through the search station, they flow fairly quickly through screening. The search station has served to regulate the flow screening, so the workers at the screening station can easily handle the arrival rate they are receiving. One of ten evacuee entities are selected for an interview. One explanation for the delay at the interview station is that one of the two resources required to complete this process is also required at another station. The same DoS worker required for the Interview is also required at Reception. Intentionally creating this 'minimal resource' environment serves to stress the system and offer a glimpse of where system limitations may appear given this manning structure. The presence of DoS personnel at the ECC should be assumed, but not guaranteed, especially given the 24 hour/day operation assumption. Modeling DoS participation as a single worker, 24 hours a day does not diminish the models validity.

4.3.2 Effect of Arrival Schedule. The effect of different arrival schedules is the next result to consider. The underlying concept is when do the bulk of evacuees arrive. Run 1 (orderly departure) over burdened the system with it's best case evenly distributed average arrivals. When this relatively steady arrival rate ramps up to include a period of greater average arrivals, the effect on Wait Time statistics are

significant as the bottlenecks are flooded even more. The difference between Runs 2 and 3 is **when** this ramp up occurs, which explains the differences between both Wait and Hour Complete Times. With the Mad Rush schedule (Run 2), the wave of evacuees hits early in the 48-hour period, and so the majority of entities are effected by the increased bottleneck. This surge has subsided toward the end of the period, so there is not a great increase in Hour Complete when compared to Run 1.

In contrast, the evacuee wave in Hesitation Schedule (Run 3) doesn't occur until later in the period. Therefore, a good number of entities are able to get through before the system really backs up, so the average times are lower that those seen in Run 2. However, this late wave bogs down the system toward the end of the period, so the Hour Complete is extended beyond those of Runs 1 and 2. Essentially, the system is never able to recover until entities stop arriving, and even then, this late backlog adds over 4 hours to the Hour Complete. These statistics are summarized in Table 11. This table also shows BP Scores for each Run. Recall the BP discussion from Section 3.5.1 which explained how this value can be understood as an evacuee's general satisfaction based on the time they waited in line. This key metric isn't analyzed here, except to say that satisfaction in all three runs is not good. It will be important to see if BP Score can be adjusted in future runs.

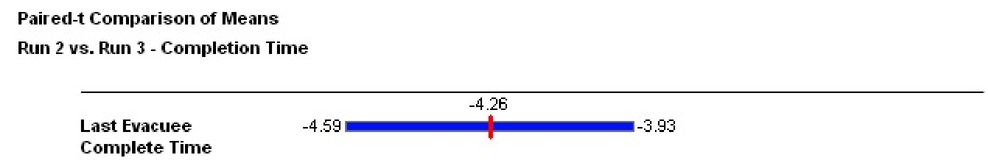
Table 11 Baseline Manning Performance Statistics

	Run 1	Run 2	Run 3
Min Wait Time	9.4	9.5	8.8
Ave Wait Time	397.1	672.1	352.6
Max Wait Time	819.6	1293.8	1005.2
Hour Complete	60.6	60.6	64.9
BP Score	39.9	39.8	49.6

* see Appendix B for complete matrix of statistic values

The analysis of Baseline data concludes with one statistical test. It is difficult to determine if the variation in values between runs is significant, or merely a function of the stochastic nature of the system. For example, is the jump in Hour Complete

between Run 2 and 3 significant? The test takes both sets of 20 Hour Complete Times, and does a comparison of their means. The results of this test, shown in Figure 10, shows that at the 95% confidence level, there is in fact a statistical difference between the two means. If zero had been included in the depicted interval, the statement at the bottom would have accepted the hypothesis that the means were equal.



Paired-T Means Comparison : Run 2 vs. Run 3 - Completion Time

IDENTIFIER	ESTD. MEAN DIFFERENCE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS
Last Evacuee Complet	-4.26	0.712	0.333	59.8	61.5	20
e Time				63.5	65.6	20

REJECT H0 => MEANS ARE NOT EQUAL AT 0.05 LEVEL

Figure 10 Paired T result - Run 2 v. Run 3: ECC Completion Time

With the first three runs thoroughly explored, the Manning Structure of the ECC is now augmented by 50%, and ran against the three arrival schedules in Runs 4, 5, & 6.

4.4 Baseline Data plus 50% (Runs 4, 5, & 6)

The analysis of the first three runs suggested that inadequate manning is contributing to long wait times. By itself, this is not an earth-shattering discovery. But the capability now exists within the model to adjust the manning at various stations and observe the result. As previously mentioned, the programmed service times also play a part. However, they are left unchanged and not explored as part of this study. To establish an upper-bound, or best case performance, the manning at every station was increased by 50% for the next set of simulation runs. Obviously increasing the manning more than this would have added benefit. However, in these days of down-sizing and budget cuts this 50% increase is merely academic.

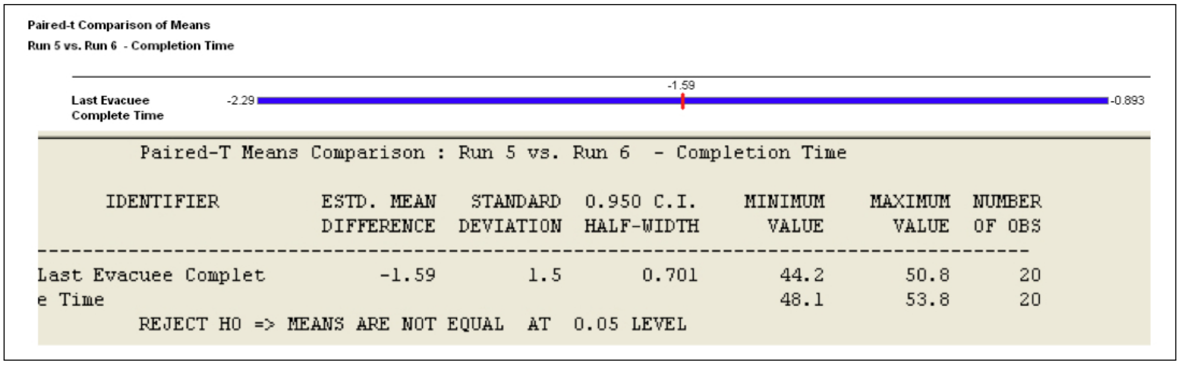
The manning was increased to the amounts already presented in Table 3 in Section 3.4 and run against the same arrival schedules. The general relationship between Runs 4, 5, & 6 mirrors those discussed in the previous section. The decreased times and increased BP Scores were anticipated, but not to this degree. Almost all maximum and average times were reduced by more than 90%, and BP Scores rose significantly. Hour Complete times dropped, but only down to around 48 hours which highlights an obvious, but important point. In this model, there are still evacuees arriving in the 47th and 48th hours. In this case, the manning allows the queues to remain small, and evacuees are handled efficiently. This can especially be seen in Run 4, where the absence of a large wave of evacuees allows the system to smoothly handle everyone almost as soon as they arrive. Figure 17 in Appendix B presents the complete data for Runs 4, 5, & 6, and allows for easy comparison.

Table 12 BLM + 50% Performance Statistics

	Run 4	Run 5	Run 6
Min Wait Time	2.6	2.9	2.9
Ave Wait Time	10.3	49.7	32.8
Max Wait Time	29.0	116.7	123.8
Hour Complete	48.4	48.2	49.9
BP Score	92.9	66.5	76.2

* see Appendix B for complete matrix of statistic values

The magnitude of the wait time reduction makes it apparent that the changes resulted in both statistical and practical difference. However, with this increased manning it appears that arrival schedule no longer drives Hour Complete differences. A Paired T test between Hour Complete values of Run 5 and 6 will show if this is true. The results, shown in Figure 11, includes the depiction of the confidence interval on the difference between the means. This interval almost includes zero, but does not. So, the conclusion of the test states they are statistically different, but in practice, the situation would dictate whether 1.5 hours is significant to the operation. The important take away from this set is that key metrics of ECC performance can be positively effected by increasing manning.



Paired-t Comparison of Means
Run 5 vs. Run 6 - Completion Time

Paired-T Means Comparison : Run 5 vs. Run 6 - Completion Time

IDENTIFIER	ESTD. MEAN DIFFERENCE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS
Last Evacuee Complet e Time	-1.59	1.5	0.701	44.2	50.8	20
				48.1	53.8	20

REJECT H0 => MEANS ARE NOT EQUAL AT 0.05 LEVEL

Figure 11 Paired T result - Run 5 v. Run 6: ECC Completion Time

4.5 Baseline Data plus 3 (Runs 7, 8, & 9)

The 50% manning increase shown in the previous section obviously benefited ECC performance, but this type of increase may not be practically feasible due to current manning constraints. From both sets of runs (1-3 & 4-6), insight is gained by observing where congestion occurs, and wait time accumulated the most. This can be seen in a number of statistics: high resource utilization, long wait time per entity and high average number of entities in specific process queues. Observing these parameters across the first six runs showed that average entities wait times were accumulating most at the reception, search and interview stations. It is important to realize at this point that the assigned process times described in Table 4 have a definite impact on these parameters. Adjusting these somewhat arbitrary values across the processes could move the bottlenecks to different stations. However, given the values presented so far, adding one additional resource at the reception, search and interview stations may reduce these lengthy queues and wait times.

Runs 7, 8, and 9 are run with the manning structure called BLM + 3, which is the original manning plus an additional worker at reception, search, and interview. As expected, all statistics moved back toward their original values from Runs 1-3. At this point, valuable comparisons sought to explore how much improvement from the baseline was realized through the addition of these 3 added bodies.

Table 13 BLM + 3 Performance Statistics

	Run 7	Run 8	Run 9
Min Wait Time	4.6	5.6	5.0
Ave Wait Time	21.1	205.3	116.5
Max Wait Time	52.4	373.8	378.2
Hour Complete	48.6	48.6	54.3
BP Score	81.6	46.9	62.6

* see Appendix B for complete matrix of statistic values

To focus the analysis even more, determining which schedule might be more likely to occur might generate more useful insight. Human behavior is unlikely to result in an arrival schedule that resembles an Orderly Departure. Left to chose between the Mad Rush and Hesitation, after action reports of real NEOs give the impression that in most situations, evacuees would tend to wait to depart, rather than rush to leave as soon as the announcement was made. Therefore, the Hesitation schedule was used to compare the BLM (Run 3) and BLM + 3 (Run 9). Figure 12 shows a more detailed description of the statistics, including not only the Average values for the 20 replications, but the maximum, minimum and 95% half-width (or confidence interval). Again, no statistical test is required to see the significance of the changes in the numbers. By inspection, you can see that no Run 3 value is contained within the Confidence interval of its Run 9 counterpart.

Simulation Run #	Alternate Manning Structures: Baseline	Alternate Manning Structures: Baseline + 2 DoS + 1 Searcher
Hesitation	3	9

20 Replications	Ave	HW	Min	Max	Ave	HW	Min	Max
Min Wait Time	8.8	0.5	6.1	10.1	5.0	0.3	3.9	6.4
Ave Wait Time	352.6	10.2	305.6	390.4	116.5	5.5	102.7	143.4
Max Wait Time	1005.2	28.7	880.1	1124.2	378.2	19.2	317.8	469.6
Ave BP Score	49.6	0.6	47.0	52.2	62.6	0.7	59.7	64.9
Hour Complete	64.9	0.3	63.5	65.6	54.3	0.3	52.9	55.5

Figure 12 Key Statistics: Run 3 vs. Run 9

It is useful to now consider these numbers in light of a real ECC with real evacuees as opposed to computer icons moving across a screen at 100 times speed. Originally, the average wait time for an evacuating entity was just shy of six hours. Except on rare occasion, most people have not be subjected to this type of wait time while physically waiting in line for service. Additionally, the ECC represented in Run 3 took an average of 16 hours to complete evacuee processing **after** the last evacuee arrived. It is reasonable to see how these lengthy waits would yield a 'very dissatisfied' BP score of barely 50 out of 100 points.

By contrast, with just three people added to this representative ECC, the average wait time fell significantly from six to just below two hours. It's again reasonable to assume this would have a significant impact on satisfaction, and in fact it does. The Average BP Score rose 13 points. The practical significance of the reduction in Hour Complete time should not be missed either. Instead of taking 16 hours after the last evacuee arrives to finish processing them, Run 9 only takes 6. This 10 hour difference has significant implications for the logistical effort required to care for evacuees in your system an additional 10 hours.

To this point, each successive set of runs has provided additional insight into how the ECC might perform under given conditions. More servers at each station obviously was very beneficial, and being able to target the reception, search and interview manning uncovered areas when small increases would be most impactful. Run nine emerged as the most likely and best performing configuration of the 9 explored so far. The final set of runs explores the alternate ECC structure and handling of evacuees with a higher likelihood to report being dissatisfied with longer wait times.

4.6 Alternate BP Structure (Runs 10, 11, & 12)

The previous nine runs were actual run within the same Arena architecture, except the mechanism to divert entities identified as BP 2s was turned 'off.' There were still BP 1s and BP 2s designated, but they all proceeded through the same queues

and stations. Wait times were collected and BP scores were assigned in accordance with the matrix outlined in Table 8. All evacuees received the same service, even through a separate BP 1 and BP 2 score was calculated. This was to establish a basis for comparing the performance of the ECC when the BP structure was activated and allowed to split evacuees into two separate processing lines. These diverter mechanisms are the choice nodes displayed as diamonds in Figure 9. Once activated via the logic syntax to split the line based on BP attribute, the manning level of BLM + 3 was assigned. The duplicate stations had 4 total workers, where 3 were retained to provide service to the BP 1s and 1 worker was dedicated to the BP 2s. For completeness, the results of these final 3 runs are displayed in Table 14 as they were for the previous 3 sets.

Table 14 Alternate BP Structure Performance Statistics

	Run 10	Run 11	Run 12
Ave Wait Time	174.8	415.9	216.0
Min BP 1 Wait Time	8.6	8.5	5.9
Min BP 2 Wait Time	0.0	0.0	0.0
Ave BP 1 Wait Time	192.7	460.7	238.6
Ave BP 2 Wait Time	10.4	11.8	11.3
Max BP 1 Wait Time	385.1	725.8	724.1
Max BP 2 Wait Time	31.2	37.8	37.2
Ave BP Score	48.6	47	59.4
Ave BP 1 Score	44.5	42.9	56.7
Ave BP 2 Score	85.7	83.9	84.5

* see Appendix B for complete matrix of statistic values

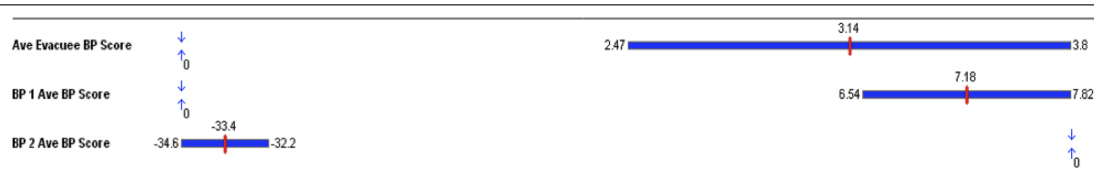
The direct comparison between Run 9 and Run 12 is shown in Figure 13 and lends substantial support to the proposition of being able to adequately effect the satisfaction of a given population, assuming they could be identified. What is introduced here is the concept of tradeoffs. The substantial improvement experienced by BP 2s comes at a price to BP 1s. The average evacuee and BP 1 Wait Times increase by roughly 100 minutes each, while the BP 2 Wait Time decreases by this same amount. The Average Satisfaction Score slips about three points and Ave BP 1

score drops a bit more than 7 as the cost of the gigantic 33 point increase in Average BP 2 Satisfaction score.

Simulation Run #	Baseline Manning + 3	
	Standard ECC Structure	BP Structure
Hesitation	9	12
20 Replications		
	Ave	Ave
Ave Wait Time	116.5	216.0
Min BP 1 Wait Time	5.1	5.9
Min BP 2 Wait Time	6.2	0.0
Ave BP 1 Wait Time	116.8	238.6
Ave BP 2 Wait Time	114.1	11.3
Max BP 1 Wait Time	378.1	724.1
Max BP 2 Wait Time	375.4	37.2
Ave BP Score	62.6	59.4
Ave BP 1 BP Score	63.9	56.7
Ave BP 2 BP Score	51.1	84.5

Figure 13 Key Statistics: Run 9 vs. Run 12

A series of Paired T tests on the BP scores are presented in Figure 14. All three comparisons show that there is a statistical difference between the means of the values being compared; Average Evacuee BP Score, Average BP 1 Score, and Average BP 2 Score.




```
        Paired-T Means Comparison : Run 9 vs. Run 12 BP Score Comparisons

     IDENTIFIER        ESTD. MEAN  STANDARD  0.950 C.I.   MINIMUM   MAXIMUM  NUMBER
                       DIFFERENCE  DEVIATION  HALF-WIDTH    VALUE     VALUE  OF OBS
-----------------------------------------------------------------------------------
Ave Evacuee BP Score         3.14      1.42       0.664      59.7        65      20
                                                            56.2      62.6      20
        REJECT H0 => MEANS ARE NOT EQUAL  AT  0.05 LEVEL
BP 1 Ave BP Score            7.18      1.37       0.642      61.1      66.2      20
                                                            53.3      59.4      20
        REJECT H0 => MEANS ARE NOT EQUAL  AT  0.05 LEVEL
BP 2 Ave BP Score           -33.4      2.58        1.21      45.4      56.5      20
                                                            82.3      86.8      20
        REJECT H0 => MEANS ARE NOT EQUAL  AT  0.05 LEVEL
```

Figure 14 Paired T results - Run 9 v. Run 12: BPS Comparisons

The concluding idea of this analysis attempts to capture the **cost** of expediting a certain section of the evacuee population. It is beyond the scope of this study to try and determine if the cost is acceptable, but merely presents them for consideration. At this point it is critical to remember the myriad assumptions that went into constructing the model. Given all the values presented in the previous chapter, Table 15 shows the percent change of the given metrics. Most telling is that BP 1s experience a 104% increase in Average Wait Time and 11% decrease in customer satisfaction, to realize a 90% decrease in Average Wait Time and 65% increase in satisfaction for the BP 2 population.

Table 15 Percent Change in Key Metrics given Alternate BPS Structure

Metric	Direction	Percent
Ave Wait Time	Inc	86%
Ave BP 1 Wait Time	Inc	104%
Ave BP 2 Wait Time	Dec	90%
Ave BP Score	Dec	5%
Ave BP 1 Score	Dec	11%
Ave BP 2 Score	Inc	65%

* BP 1 = 90% of evacuees, BP 2 = 10%

4.7 Conclusion

This chapter presented the results of the simulation runs in a manner that reflected the thought process used during the analysis. It began by exploring the performance of the ECC model given a baseline manning structure as recommend by the SME. The initial runs also showed the effect that arrival distribution can have on performance. The next set of runs demonstrated the type of improvement that could be realized by increasing manning at all stations. The third set of runs explored the types of gains that could be possible by augmenting the original manning by a more reasonable amount. This third manning iteration of BLM + 3 was shown to be statistically and practically better than the original. Additionally, it was argued that the Hesitation schedule was a reasonable scenario to take forward into additional

analysis. Finally, an alternate ECC structure was introduced that allowed for separate handling of a portion of the evacuee population. It was shown that dedicated resources applied to this identified subpopulation could significantly decrease their wait times and improve their processing experience, however at a cost to the rest of the evacuees.

5. Conclusions & Recommended Future Efforts

A Noncombatant Evacuation Operation is a very dynamic process. The DoD is charged to assist DoS in NEO execution, but must be prepared to take the lead and carryout all phases alone if the situation requires it. This uncertainty complicates the already difficult NEO planning process. This NEO effort was divided into two separate, but coordinated studies; one explored the Evacuation Control Center, and the other modeled the transportation elements required to move evacuees from the ECC to a designated Safe Haven. The two resulting models are able to be 'plugged' together to represent the greater NEO operation, representing the flow of evacuation entities from arrival at the ECC to drop-off at the Safe Haven. This single NEO model is one of the valuable contributions this combined study has made to the broader area of NEO research and anaylsis. The model inputs can be altered to reflect a specific location, or particular parameters of interest. In this way, NEO planners could gain more than generic ECC operation understanding, but abstract location and situation-specific insight.

After providing a brief NEO introduction, this paper presented a few of the adjacent areas of study which share common elements with NEOs. The methodology used to construct the model was addressed in detail, followed by an analysis of the 12 different simulation runs that comprised the study. This final chapter will reemphasize the driving assumptions, present the key take-aways, and suggest criteria and a direction for future research.

5.1 Key Take-Aways

The importance of understanding the driving assumptions cannot be over-stated with regards to a simulation analysis or study. Decision maker insights are gleaned from the simulation results and analysis. These results are often directly, and always at least indirectly tied to the assumptions used to build the simulation. A ready knowledge of the assumptions is critical to truly understand what the results are saying, and more importantly, what they are **not** saying. Although these uncertainties

have already been addressed, it is appropriate to readdress them as an important aspect of formulating key take-aways. Some of the key areas when information had to be assumed:

- number of evacuation entities
- attributes and characteristics of the entities
- didn't model dealing with pets
- didn't model directive requiring female screener for female evacuees
- evacuee arrival distribution to the ECC
- ECC operating 24 hours per day
- number of DoS personnel to expect as part of the ECC manning structure
- station service time distribution
- number of entities selected for interview and/or detention
- proportion of evacuee population in need of medical assistance
- ability to ascertain evacuees more prone to voicing dissatisfaction.

This assumptions color the lens through which the results and analysis may be viewed. The power of a simulation study is often in its ability to make comparisons, not necessarily arrive at one final correct numeric solution. The way the statistics change in both magnitude and direction throughout the runs are a much more useful insight than the numbers themselves. The results previously presented lead to these key take-aways:

- evacuee arrival rate and distribution to the ECC has a significant impact on wait times, queue lengths, and completion times experienced in the ECC
- number of workers per process, combined with service times plays a large role in bottlenecks
- bottlenecks early in the flow will have more damaging effect to overall system performance
- the station immediately following the initial reception should be given the most scrutiny and dedicated resources to absorb the shock of the evacuee wave after each reception
- practical improvement can be made to system performance with small targeted increases in manning
- minor adjustments to ECC structure and reapportionment of manning can significantly improve the processing experience of a portion of the population, but at a price to the rest

5.2 Recommended Future Efforts

Any future effort must also be accompanied by a greater dose of leadership support and interagency cooperation. Dialogue with both DoS and the Transportation Security Administration would be hugely beneficial. However, without a high ranking 'champion' to pave the way for these partnerships, relatively low ranking students and academicians are not likely to be able to successfully initiate productive inter-Department and Joint efforts. This increased top-cover should also enable access units who have executed the NEOs of 2010 and 2011. The personal testimony of both DoS and DoD personnel who had an active roll in these NEOs would be very valuable. Hopefully these contacts could also provide some amount of real-world, NEO execution data, that could be incorporated in the future work.

Its dynamic nature and lack of readily available data presents a challenge to studying NEO via simulation. The insights gained have potential power, but are still based on a generic scenario. Further refinement of this generic model may not be as useful as efforts to begin to thoroughly explore and reduce some of the assumptions listed previously. Specially, a better knowledge of service times and distributions for the different ECC functions would improve model specificity. Observing MEU ECC operations training or evaluations would be beneficial, along with additional work with Industrial Engineers to truly engineer the ECC mechanisms.

Additional sensitivity analyses should be conducted to determine how performance varies with attribute and service time distributions. If bounds could be placed on these parameters, planners could attempt to classify actual locations as within these bounds or outside. This would lend fidelity to anticipated ECC performance. Only once these areas are better understood would it be valuable to add additional fidelity to the model incorporating characteristics such as: female searcher for female evacuees, how to process evacuee pets, and different levels of evacuee priority status.

This study focused on the types of gains that could be realized, but stopped short of the dangerous questions of value and worth. For example, alternate manning

and processing structures were presented and recommended. No effort was made to assess any type of cost, or how different stakeholders in this multi-agency process would feel about these kinds of changes. The Decision Analysis discipline is suited to explore systems, processes or decisions with multiple alternatives, each having multiple attributes. A better understanding of tradeoffs and alternative value would result if a value model was created for a given NEO situation, with access to actual decision makers to elicit their priorities. Simulation results could still be incorporated, but now an assessment of the cost (both financially and otherwise) could be included. This would give a clearer picture of the real decision space both DoS and DoD leadership would find themselves in given a real NEO.

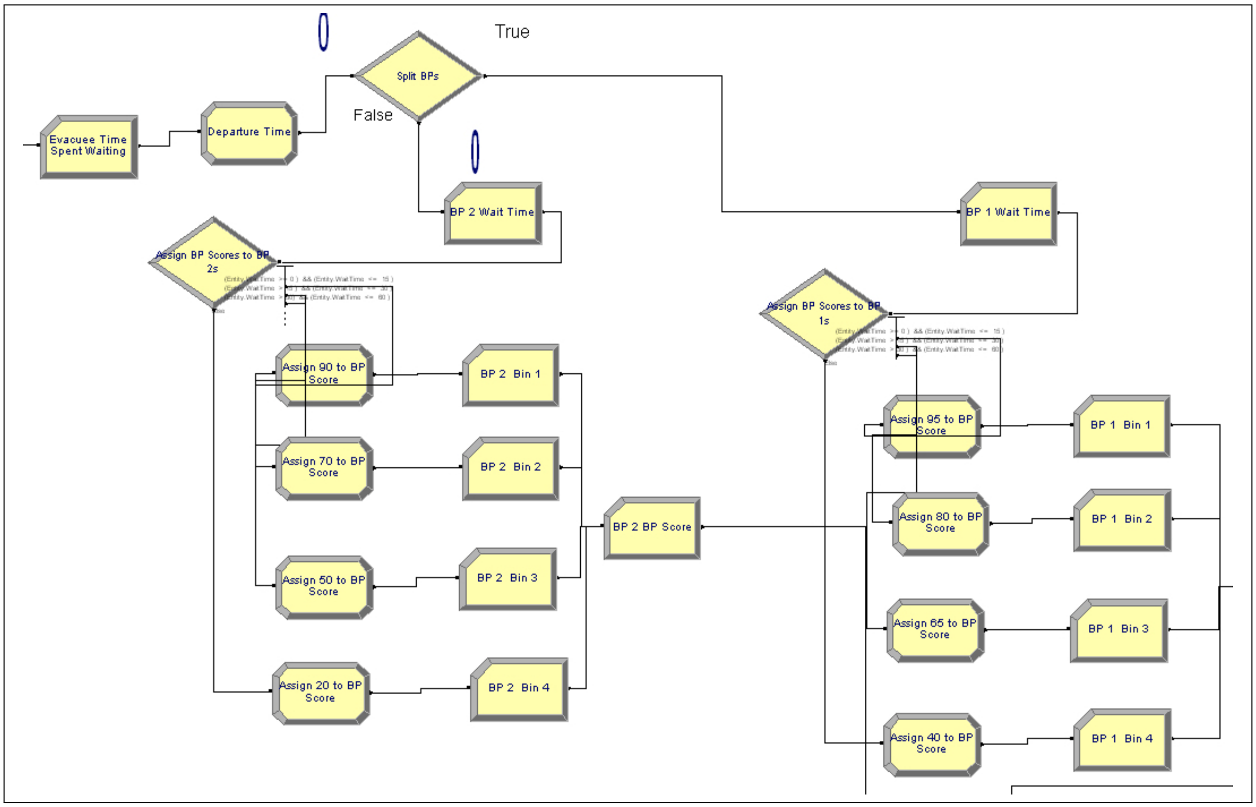


Figure 15 Arena - Statistics Collection Submodel

Resource - Basic Process

	Name	Type	Capacity
1	DoS Rep	Fixed Capacity	1
2	Counter Intel	Fixed Capacity	1
3	Med Rep	Fixed Capacity	2
4	BP1 Searcher	Fixed Capacity	3
5	BP2 Searcher	Fixed Capacity	0
6	BP1 Screener	Fixed Capacity	4
7	BP2 Screener	Fixed Capacity	0
8	BP1 Data Entry NTS	Fixed Capacity	4
9	BP2 Data Entry NTS	Fixed Capacity	0

Decide - Basic Process

	Name	Type	Percent True	If	Attribute Name	Is	Value
1	Selected for Interview	2-way by Condition	50	Attribute	attInterview	>=	2
2	Continue ECC processing	2-way by Chance	99	Attribute	IntCat	>=	1
3	Medical Processing Reqd	2-way by Condition	50	Attribute	attMedical	>=	2
4	Split line by BP	2-way by Condition	50	Attribute	BPNum	==	1
5	Split line by BP Again	2-way by Condition	50	Attribute	BPNum	==	1

Process - Basic Process

	Name	Type	Action	Priority	Resources	Delay Type	Units	Allocation	Minimum	Value	Maximum	Expression
1	Reception	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	8	10	12,11	attReceptionTime
2	BP1 Search	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	4	5	7,12	TRIA(2,3,4,12) * (1 + (attNumFam *.3))
3	BP1 Screen	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	1	3	5,13	TRIA(1,3,5,13) * (1 + (attNumFam * .2))
4	Interview	Standard	Seize Delay Release	Medium(2)	2 rows	Triangular	Minutes	Value Added	3	5	10,15	1
5	BP1 Registration	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	3	5	7,14	TRIA(1,3,5,14) * (1 + (attNumFam * .3))
6	Med Processing	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	.5	1	1.5	2 + (attMedical * 2)
7	Processing Complete	Standard	Delay	Medium(2)	0 rows	Constant	Minutes	Value Added	1	0	3	1
8	BP2 Search	Standard	Seize Delay Release	High(1)	1 rows	Expression	Minutes	Value Added	4	5	7,12	TRIA(2,3,4,12) * (1 + (attNumFam *.3))
9	BP2 Screen	Standard	Seize Delay Release	High(1)	1 rows	Expression	Minutes	Value Added	3	4	6,13	TRIA(1,3,5,13) * (1 + (attNumFam * .2))
10	BP2 Registration	Standard	Seize Delay Release	High(1)	1 rows	Expression	Minutes	Value Added	3	4	7,14	TRIA(1,3,5,14) * (1 + (attNumFam * .3))

Figure 16 Arena - Resource, Process, & Decision Descriptions

Appendix B. Key Statistic Matrix: Runs 1-12

Table 16 Simulation Run Reference Number

Arrival Dist.	BLM*	BLM+50%	BLM+3**	Alt BP Structure***
Mad Rush	2	5	8	11
Orderly	1	4	7	10
Hesitation	3	6	9	12

* Baseline Manning
** adds 1 DoS rep for Reception, 1 Interviewer, and 1 Searcher
*** Alternate ECC Structure with BLM + Target Plus-up manning

Simulation Run #	Alternate Manning Structures		
	Baseline	Baseline + 50%	Baseline + 2 DoS + 1 Searcher
Mad Rush	2	5	8
Orderly Departure	1	4	7
Hesitation	3	6	9

20 Replications	Ave	HW	Min	Max	Ave	HW	Min	Max	Ave	HW	Min	Max
Min Wait Time	9.4	1.3	4.5	14.3	2.9	0.3	1.6	3.9	5.6	0.5	4.2	7.3
Ave Wait Time	672.1	20.4	598.4	754.1	49.7	7.0	29.1	77.2	205.3	17.3	158.6	307.8
Max Wait Time	1293.8	48.6	1122.3	1497.4	116.7	12.3	76.8	164.7	373.8	23.6	300.8	511.9
Ave BP Score	39.8	0.2	39.0	40.6	66.5	2.4	58.5	75.7	46.9	1.1	42.4	50.2
Hour Complete	60.6	0.2	59.8	61.5	48.2	0.8	44.2	50.8	48.6	0.7	45.6	50.1
Min Wait Time	9.5	1.3	4.6	14.7	2.6	0.3	1.4	3.7	4.6	0.4	3.7	7.0
Ave Wait Time	397.1	15.5	346.6	477.9	10.3	0.1	10.0	10.8	21.1	3.5	15.2	47.6
Max Wait Time	819.6	43.7	680.8	1038.5	29.0	1.2	25.5	34.2	52.4	6.9	32.9	88.4
Ave BP Score	39.9	0.2	39.1	40.9	92.9	0.1	92.2	93.4	81.6	2.9	60.3	87.4
Hour Complete	60.6	0.2	60.1	61.5	48.4	0.5	46.5	50.2	48.6	0.5	45.7	50.5
Min Wait Time	8.8	0.5	6.1	10.1	2.9	0.3	1.8	3.7	5.0	0.3	3.9	6.4
Ave Wait Time	352.6	10.2	305.6	390.4	32.8	3.1	22.5	50.5	116.5	5.5	102.7	143.4
Max Wait Time	1005.2	28.7	880.1	1124.2	123.9	10.8	84.8	181.8	378.2	19.2	317.8	469.6
Ave BP Score	49.6	0.6	47.0	52.2	76.2	1.3	70.3	81.1	62.6	0.7	59.7	64.9
Hour Complete	64.9	0.3	63.5	65.6	49.9	0.7	48.1	53.8	54.3	0.3	52.9	55.5

Figure 17 Key Statistics - Runs 1 - 9

Simulation Run #	Baseline Manning + 3	
	Standard ECC Structure	BP Structure
Mad Rush	8	11
Orderly Departure	7	10
Hesitation	9	12

20 Replications	Ave	Ave
Ave Wait Time	205.3	415.9
Min BP 1 Wait Time	5.8	8.5
Min BP 2 Wait Time	7.2	0.0
Ave BP 1 Wait Time	205.5	460.7
Ave BP 2 Wait Time	203.5	11.8
Max BP 1 Wait Time	373.7	725.8
Max BP 2 Wait Time	371.0	37.8
Ave BP Score	46.9	47.0
Ave BP 1 BP Score	48.7	42.9
Ave BP 2 BP Score	30.6	83.9
	Ave	Ave
Ave Wait Time	21.1	174.8
Min BP 1 Wait Time	4.7	8.6
Min BP 2 Wait Time	6.4	0.0
Ave BP 1 Wait Time	21.2	192.7
Ave BP 2 Wait Time	20.9	10.4
Max BP 1 Wait Time	52.4	385.1
Max BP 2 Wait Time	48.1	31.2
Ave BP Score	81.6	48.6
Ave BP 1 BP Score	82.4	44.5
Ave BP 2 BP Score	73.6	85.7
	Ave	Ave
Ave Wait Time	116.5	216.0
Min BP 1 Wait Time	5.1	5.9
Min BP 2 Wait Time	6.2	0.0
Ave BP 1 Wait Time	116.8	238.6
Ave BP 2 Wait Time	114.1	11.3
Max BP 1 Wait Time	378.1	724.1
Max BP 2 Wait Time	375.4	37.2
Ave BP Score	62.6	59.4
Ave BP 1 BP Score	63.9	56.7
Ave BP 2 BP Score	51.1	84.5

Figure 18 Dissatisfaction Parameter Comparison - Runs 7 - 12

Appendix C. Blue Dart

Americans Living Abroad May Be In Harms Way Too Long

Christopher Olsen, Major, USAF

christopher.olsen@afit.edu

Word Count: 504

Current Non-combatant Evacuation Operation (NEO) processes have not been adequately engineered or optimized to ensure the most efficient evacuation of American citizens from potentially life threatening situations. Tumultuous world events support the argument that a re-examination of this process is warranted. If the United States considers it a priority to offer protection and safe evacuation to its citizens abroad during life threatening circumstances, then resources must be committed to objectively analyze the current process, followed by a rigorous examination of alternative solutions.

The inter-agency nature of these operations present many planning complexities as a NEO is a Department of State effort, occasionally executed with Department of Defense assistance. Key operation planners, responsible for the design of country-specific NEO plans, suspect the Evacuation Control Center contains inefficiencies in the way it process evacuees. Simulating the ECC will highlight key parameters, identify potential bottlenecks, and provide insight to decision makers on which areas of the process would benefit most from commitment of future resources.

A number of the challenging characteristics of a NEO are present in other applications as well. Disaster relief planning shares the common thread of rapidly transporting a great number of people in a very dynamic environment. Accountability, speed and safety are driving factors in both scenarios. Constructive dialogue with agencies currently engaged in disaster relief planning may prove beneficial for ECC optimization efforts. The Army Corps of Engineers, Department of Homeland Security, Transportation Security Administration and university Industrial Engineering departments all hold promise as sources worth pairing with in looking at ECC efficiency.

In addition to the speed of evacuee processing, there is a psychological component to these types of operations. Processing and transporting people in a stressful and possibly dangerous environment deserves some people-focused attention. Operational success is sometimes driven by the perceptions of those who were directly involved. The CNN-effect can drastically influence public opinion, and in this case drive how perception of how the United States handled a delicate situation and protection and removal of its citizens. In addition to optimizing ECC efficiency, efforts to maximize evacuee comfort and perception of being adequately taken care of should also be investigated. Disney employees a team of industrial engineers who apply their craft to varying functions and processes throughout Disney operations. Receiving, process, and transporting large number of people, while giving each one a sense that they are being taken care of is a quality that can be seen in both Disney operations and a NEO. Obviously there are some significant differences, but there are enough similarities that communication and sharing of ideas should be pursued.

Evacuee arrival patterns, station manning levels, and alternate operating structures are evaluated and compared. These comparisons access the adequacy of prescribed manning levels and show that the addition of just a few workers in key positions can produce dramatic improvement. Finally, the study lends quantified support to the premise that customer wait time, and thereby satisfaction, can be improved for a certain evacuee sub-population, but at a price to the remaining evacuees.

Major Christopher Olsen is a graduate student in the IDE Operations Analysis program at the Air Force Institute of Technology

Keywords: Noncombatant Evacuation Operation, Evacuation Control Center

Bibliography

Banks, J., J. Carson, B. Nelson, and D. Nicol (2010). *Discrete Event System Simulation - 5th Ed.* Upper Saddle River, NJ: Pearson.

Buczkowski, P. (2011, February). Phone interview. Disney, Office of Industrial Engineering.

Bureau, U. C. (2011, January). United states census 2000. `http://www.census.gov/population/www/cen2000/briefs/`. Census 2000 Briefs.

Davis, M. A. (2007). Joint considerations for planning and conducting noncombatant evacuation operations. Master's thesis, Naval War College, Joint Military Operations Department, Newport, Rhode Island.

Department of Defense (2010, December). *JP-3-68; Noncombatant Evacuation Operations.* United States Office of the Chairman of the Joint Chiefs of Staff.

Ford, J. (2007, April). State department: The july 2006 evacuation of american citizens from lebanon.

Gregg, A. M. (2010). Optimizing crisis action planning in the noncombatant evacuation operation setting. Master's thesis, Air Force Institute of Technology, Wright Patterson AFB, Ohio.

Lim, G. (2011, January). Phone interview. University of Houston, Department of Industrial Engineering.

Livingston, M. (2011a, January). Meu ecc training - 'neo 101'.

Livingston, M. (2011b, January). Phone interview. EUCOM/J3.

Reagan, R. (2011, March). Executive order 12656. `http://www.fas.org/irp/offdocs/EO12656.htm`.

Standifer, K. M. (2008). Working together during noncombatant evacuation operations. Master's thesis, Naval War College, Joint Military Operations Department, Newport, Rhode Island.

Vita

Major Christopher Olsen graduated from Hamburg High School, Hamburg, New York in 1994. He received a commission from the United States Air Force Academy in May of 1998, graduating with a Bachelor of Science Degree, Engineering Sciences, Aeronautical Engineering Emphasis.

After graduating from Euro-Nato Joint Jet Pilot Training in 2000, he was selected to fly the F-16. Following initial training at Luke AFB, AZ, his first operational F-16 assignment was the 34th Fighter Squadron at Hill AFB, UT from 2001 to 2004. He continued flying the F-16 at Osan AB, Republic of South Korea from 2004 to 2006. Chris's went on to be an instructor in the Introduction to Fighter Fundamentals program at Randolph AFB, TX flying the T-38C. After graduation from the Graduate School of Engineering and Management, Air Force Institute of Technology, Chris will serve as the Chief of Flight Safety Issues, Headquarters Air Force.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 074-0188*

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to an penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
16-06-2011	IDE Graduate Research Paper	Dec 2010-Jun 2011

4. TITLE AND SUBTITLE	
Simulation Study of Evacuation Control Center Operations Analysis	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
Olsen, Christopher M., Major, USAF	**5e. TASK NUMBER**
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way, Building 640 WPAFB OH 45433-8865	AFIT/IOA/ENS/11-04
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
European Command/J3 DSN: 314-430-4286 Jeff White, LT, USN email: whitejk@eucom.mil CMR 480 Box 3075 APO, AE 09128	**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

A Noncombatant Evacuation Operation (NEO) is the primary method employed by the US State Department of safely evacuating American Citizens and designated host country nationals from life threatening situations in foreign countries. Planning for these operations is difficult due to its dynamic nature and complex inter-department command and execution structure. Planning efficiencies could be realized through insights into dependencies and fundamental NEO operating characteristics. The Evacuation Control Center (ECC) is a main component in evacuee flow. This simulation study models ECC operations in Arena and varies key inputs and parameters to uncover the underlying elements that drive ECC output and performance. Evacuee arrival distribution, ECC manning, and evacuee wait times are the main parameters of interest.

15. SUBJECT TERMS

Noncombatant Evacuation Operation, Evacuation Control Center

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Miller, John O., Civ, USAF
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
U	U	U	U	64	(937) 255-6565, ext 4326 (john.miller@afit.edu)

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18